The Bell System Technical Journal
Vol. 53, No. 2, February 1974
Printed in U.S.A.

B.S.T.J. BRIEFS

Interframe *Picturephone*® Coding Using Unconditional Vertical and Temporal Subsampling Techniques

By R. T. BOBILIN

(Manuscript received November 8, 1973)

I. INTRODUCTION

A number of articles[1–4] have described the use of horizontal redundancy removal techniques to reduce the transmission rate required for coded *Picturephone*® signals to 6.312 Mb/s. Here an extension of this work is given which uses unconditional vertical and temporal subsampling techniques to reduce the required transmission capacity to 3 Mb/s. This type of processing is unique in that it does not employ the complex conditional replenishment techniques which typically have been used to reduce the digital transmission rate to either 2 Mb/s[5] or 1.5 Mb/s.[6]

II. SYSTEM DESCRIPTION

The analog *Picturephone* signal has an interlaced frame format[7] as illustrated in Fig. 1. Two adjacent fields, each containing $125\frac{1}{2}$ alternating lines, combine to form a complete 251-line frame of video information. In the experimental system being described, two adjacent fields are "averaged" together at the coder; this averaged $125\frac{1}{2}$ line field is processed using variable-length coding techniques[3] and sent to the decoder at a 30-Hz rate. The decoder processes the received averaged field to form a two-field, 251-line frame for transmission to the station set receiver. Hence, unconditional vertical and temporal subsampling is being used to reduce the digital transmission rate from 6 Mb/s to 3 Mb/s; vertical subsampling because only $125\frac{1}{2}$ lines per frame are transmitted and temporal subsampling because averaged

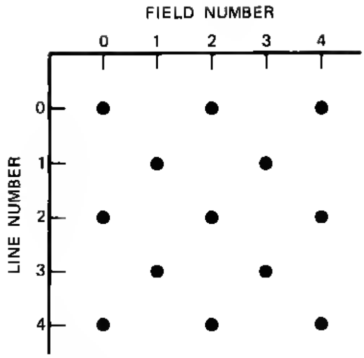

Fig. 1—Interlaced frame format.

fields are only transmitted at a 30-Hz rate instead of the original 60-Hz rate. The hasis for this unconditional vertical suhsampling is that the vertical spatial dimension of a *Picturephone* signal does not contain 251 lines of detail. There is no vertical aperture correction circuitry in the station set and the actual resolution is much closer to the $125\frac{1}{2}$ lines contained in one field of the interlace pattern; the vertical amplitude response of the station set transmitter varies from 8 to 27 dB down at half the field sampling rate ($125\frac{1}{2}$ video lines/2), depending on the control unit settings at the transmitter. This is not a station set design failure hut a requirement to prevent ohjectionahle vertical aliasing effects in the displayed scene. In the temporal dimension the required signal properties are harder to define hecause the postfiltering action of the human eye dominates system parameters. It is known that a 60-Hz field repetition rate was chosen on the hasis of flicker sensitivity, not on the hasis of motion rendition, hut the application of general eye temporal sensitivity studies to the present *Picturephone* format is of questionahle value and leads to inconclusive results. Therefore, an experimental 3-Mh/s codec was huilt hoth to verify the vertical processing predictions and to see if 30-Hz transmission is suhjectively acceptahle in the present *Picturephone* system.

A hlock diagram of the experimental system is given in Fig. 2. Prior to A/D conversion the analog video signal is deemphasized, equalized, clamped, and filtered with a crispened Gaussian filter that is 20 dB down at 1 MHz. The A/D converter uses a synchronized 1.536-MHz clock to produce an 8-hit PCM word at each sample time. The input to the variahle-length coder (VLC) is either the unfiltered (no vertical or temporal filtering) output of the A/D converter or a

filtered version of the same signal. This is done so that an easy AB test can be made to determine the effects of additional vertical and temporal prefiltering. In the unfiltered case the input to the VLC during time i is field i (f_i); in the filtered case the input is the average of field i (f_i) and an estimate of field i based on the information contained in field $i - 1$ ($\hat{f}_{i-1}$). If line j is in field i, then the estimate of line j from field $i - 1$ is given by:

$$\bar{l}_j = \frac{l_{j-5} - 3l_{j-3} + 10l_{j-1} + 10l_{j+1} - 3l_{j+3} + l_{j+5}}{16}. \tag{1}$$

$\bar{l}_j$ is an estimate of even fields from odd fields and vice versa. This particular estimator gives adequate filtering performance and is easy to implement. The variable-length coder and decoder are the same as described in Ref. 3 and process either every other field or every other average field. The vertical and temporal postfilter uses the received 30-Hz fields to reconstruct the proper 60-Hz even-odd field pattern for the station set receiver. Again two options were designed for the postfilter. In the vertical dimension both postfilters are the same and estimate an adjacent field using the relationship given in (1); in the

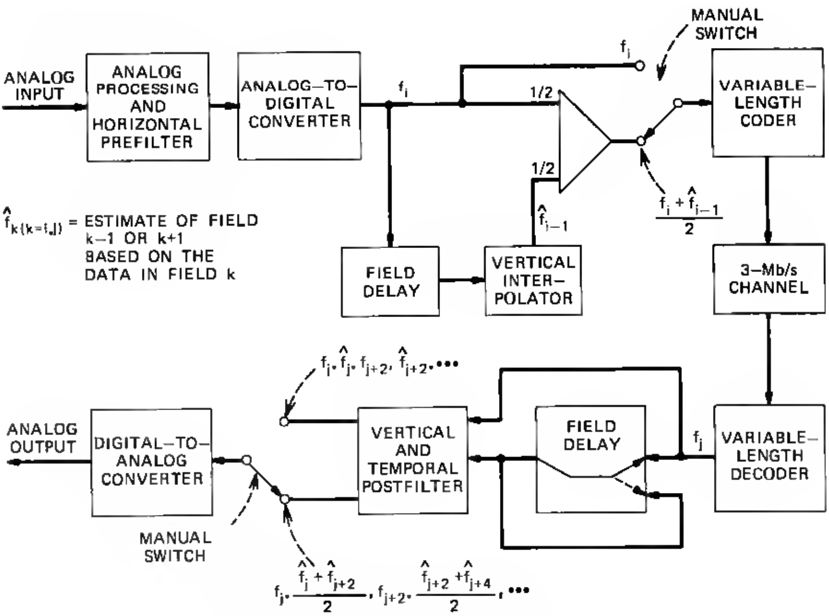

Fig. 2—Experimental system block diagram.

time domain the postfilter using the estimate $\hat{f}_j$ is a sample-and-hold postfilter, whereas the one using the estimate $(\hat{f}_j + \hat{f}_{j+2})/2$ is an interpolating postfilter. The D/A converter turns the 8-bit 1.536-MHz PCM samples into an analog format.

III. SUBJECTIVE RESULTS

When the station set transmitter is operating in its highest resolution condition, with no zoom, and when the coder prefilter is not used, then vertical aliasing is easily seen on eyeglass rims and around the lips. This aliasing can be eliminated either by using the coder vertical prefilter or by placing the station set in a partial-zoom mode. Both changes have the effect of introducing additional vertical prefiltering; the coder vertical prefilter adds 6 dB of vertical filtering at half the sampling rate or $62\frac{3}{4}$ lines per frame and the use of the zoom mode adds filtering proportional to the setting, somewhere between 8 and 27 dB at $62\frac{3}{4}$ lines per frame. The effect of the temporal prefiltering associated with the coder field filtering is insignificant.

The use of the sample-and-hold postfilter (3 dB down at 15 Hz) results in a slight jerkiness of motion (temporal aliasing) which is completely removed by using the interpolating postfilter which is 6 dB down at 15 Hz.

In order to evaluate this 3-Mb/s codec a series of subjective tests were developed. Fifteen people were given an AB test between the analog and the coded video (using field filtering at the coder and the interpolating postfilter at the decoder) and were asked if the impairment added by the codec was:

1. Not noticeable
2. Just noticeable
3. Noticeable but not objectionable
4. Objectionable
5. Extremely objectionable.

In this test each observer was given 15 seconds of analog followed by 15 seconds of the coded scene shown in Fig. 3. During each 15-second interval, Bonnie carried on a normal conversation for the first 5 seconds, moved from side to side for the next 5 seconds, and again carried on a normal conversation for the last 5 seconds. With the station set in its high-resolution mode, no zoom, the average scale rating was 2.8 indicating that for this scene the impairment added by the 3-Mb/s codec was noticeable but not objectionable; with the station set in a partial-zoom mode the average scale rating was 2.3 indicating an

Fig. 3—Bonnie.

impairment tbat is just noticeable. These comment scale ratings can be compared with a more complete series of tests carried out using the same horizontal processing without any vertical or temporal processing on three different scencs. Tbis resulted in an overall average scale rating of 2.1 for the corresponding 6-Mb/s codec.[4]

IV. CONCLUSIONS

An experimental system bas been built showing that unconditional vertical and temporal subsampling techniques can be used on a 6-Mb/s intraframe codec to result in a 3-Mb/s interframe codec. The impairment resulting from this 3-Mb/s codec is rated as being between just noticeable and noticeable but not objectionable. This unconditional alternate field transmission technique can also be used as a higher

activity mode in a conditional replenishment type codec as shown in Ref. 6.

REFERENCES

1. J. B. Millard and H. I. Maunsell, "The *Picturephone*® System: Digital Encoding of the Video Signal," B.S.T.J., *50*, No. 2 (February 1971), pp. 459–479.
2. R. P. Abbott, "A Differential Pulse-Code-Modulation Coder for Videotelephony Using Four Bits Per Sample," IEEE Trans. Commun. Tech., *COM-19*, No. 6, Part 1 (December 1971), pp. 907–912.
3. M. C. Chow, "Variable Length Redundancy Removal Coders for Differentially Coded Video Telephone Signals," IEEE Trans. Commun. Tech., *COM-19*, No. 6, Part 1 (December 1971), pp. 923–926.
4. R. T. Bohilin, "Prefilters, Sampling, and Transmission Rates for Intraframe Codecs for *Picturephone*® Service," B.S.T.J., *52*, No. 4 (April 1973), pp. 497–525.
5. J. C. Candy, Mrs. M. A. Franke, B. G. Haskell, and F. W. Mounts, "Transmitting Television as Clusters of Frame-to-Frame Differences," B.S.T.J., *50*, No. 6 (July-August 1971), pp. 1889–1917.
6. Y. C. Ching, B. Gotz, D. M. Henderson, and J. B. Millard, "Video Processing System (VPS)—A Conditional Replenishment Interframe Codec for the Digital Transmission of *Picturephone*® Signals at the T1 Rate," unpublished work.
7. W. B. Cagle, R. R. Stokes, and B. A. Wright, "The *Picturephone*® System: 2C Video Telephone Station Set," B.S.T.J., *50*, No. 2 (February 1971), pp. 271–312.

Simultaneous Measurements of Depolarization by Rain Using Linear and Circular Polarizations at 18 GHz

By R. A. SEMPLAK

(Manuscript received August 3, 1973)

I. INTRODUCTION

Limitations imposed by attenuation during heavy rain on the reliability of microwave systems are well known[1] and a recent paper[2] discussed observations of depolarization of circular polarization by rain at 18 GHz; it was concluded that depolarization by oblate raindrops poses a serious problem for the use of circular polarization. However, it is desirable that a direct comparison be made by *simultaneous* measurements of linear and circular polarizations on the same propagation path. Continuous measurements have been made during the period June 1972 through April 1973 (a total of 35 rain showers); a discussion of these follows a few remarks on the experimental system.